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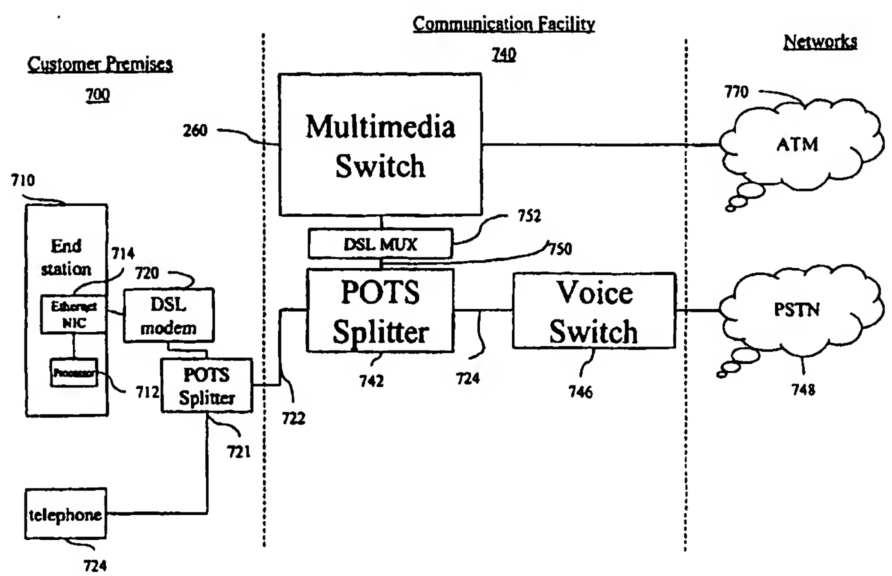
(54) Title: A COMMUNICATION SYSTEM FOR TRANSPORTING MULTIMEDIA INFORMATION OVER HIGH-SPEED LINKS USING AN ETHERNET TYPE NETWORK INTERFACE



(57) Abstract: Multimedia information, voice, video, image, and data, is transported over a cell switching communications network to a multimedia switch that performs cell to frame and frame to cell conversions. With a negotiated quality of service and explicit rate flow control with RM cell priority, the frames are transported over a high-speed link to a remote desktop, which contains an Ethernet type network interface device for processing the frames. The high-speed link is typically a digital subscriber line twisted pair or coaxial cable via a cable modem.

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A COMMUNICATION SYSTEM FOR TRANSPORTING MULTIMEDIA INFORMATION OVER HIGH-SPEED LINKS USING AN ETHERNET TYPE NETWORK INTERFACE

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

The present invention relates to a communication system, which provides multimedia services, i.e., textual, graphical, image, video, voice and audio, to remote users over high-speed links. The present invention also relates to providing end-to-end Quality of Service and Available Bit Rate with Explicit Rate flow-control with RM cell priority associated with ATM networks when delivering the multimedia services. In particular, the present invention is directed to end-users with Ethernet-type interface capabilities used in a DSL or cable modem environment.

BACKGROUND ART

As the information age matures, it is enabled by a number of technological advances, such as the geometric growth of networked computing power and the prevalence of reliable and ubiquitous transmission media. Today's consumers in both the residential and business arena have been acclimated to a more graphical approach to communication. In particular, multimedia applications (which include textual, graphical, image, video, voice and audio information) have become increasingly popular and find usage in science, business, and entertainment. Local area networks (LANs) are essential to the productivity of the modern workplace; Ethernet-type networks have dominated the LAN market

and have been continually enhanced (e.g., switched Ethernet, Fast Ethernet, and/or Gigabit Ethernet) to keep pace with the bandwidth intensive multimedia applications.

A compelling example of the growth of information consumption is the dramatic increase in users of the World Wide Web, a multimedia-based information service provided via the Internet. Although initially a forum for academia to exchange ideas captured in ASCII text, the Internet has developed to become a global media for users from all walks of life. These Internet users regularly exchange multimedia graphical, image, video, voice and audio information as well as text.

Furthermore, the business world has come to realize tremendous value in encouraging workers to telecommute. To avoid the idle commuting time, today's workers enjoy the convenience of working from home via their personal computers. As illustrated in Figure 1, a user at a remote site 101 (e.g., home) has traditionally been able to access her/his office 119, which includes accessing an office local area network 119b (LAN), through a dial-up connection over a 33Kbps or 56Kbps modem 101b. The dial-up connection is handled by a telephone central office (CO) 105 through a voice switch 107, which switches the "data" call through a public switched telephone network (PSTN) 111. The data call terminates in a remote CO 121 at a voice switch 123. The voice switch 123 switches the call to the subscriber; in this case, the called line is associated with a modem in a modem pool 119a. Once connected to the modem pool 119a, the end user at her/his remote site 101 can access the computing resources in his office 119. These sources include a multimedia server 119c and a PC 119d of the remote user. A similar connection to Internet 115 by a user at a remote site 101 can be accomplished by connecting to an Internet Service Provider (ISP) 117 instead of modem pool 119c.

Unfortunately, telecommuting from a remote office or accessing multimedia information from home over the Internet imposes an enormous strain on networking resources. It is common knowledge that the networking infrastructure is the bottleneck to the expedient transfer of information, especially bandwidth intensive multimedia data. As alluded to before, today's access methods are limited to standard analog modems, such as 101b, which have a

maximum throughput of 56 Kbps on a clean line (i.e., a line not having any appreciable noise causing errors in bit rate transfer). Remote users may alternatively acquire basic rate (2B+D) Integrated Services Digital Network (ISDN) services at 128kbps. Even at this speed, telecommuters may quickly grow impatient with slow response times as compared to the throughput of their LANs to which they have grown accustomed. On average, a typical Ethernet user can expect to achieve approximately 1Mbps on a shared 10Base-T Ethernet LAN and up to 9+Mbps in a full duplex switched Ethernet environment. In addition, Internet users are also demanding greater access speeds to cope with the various multimedia applications that are continually being developed. Fortunately, the communication industry has recognized the escalating demand.

Cell switching technology, such as Asynchronous Transfer Mode (ATM), was developed in part because of the need to provide a high-speed backbone network for the transport of various types of traffic, including voice, data, image, and video. An ATM network 113 is typically able to provide bandwidths to an ATM user at approximately 1.5 Mbps on a T1 line, 44.7 Mbps on a T3 line, and 155 Mbps over a fiber optic OC-3c line. Consequently, ATM networks are suitable to transport multimedia information.

ATM further provides a mechanism for establishing quality of service (QOS) classes during the virtual channel setup, thereby allotting a predetermined amount of bandwidth to the channel. QOS classes define five broad categories that are outlined, for example, by the ATM Forum's UNI 3.0/3.1 specification. Class 1 specifies performance requirements and indicates that ATM's quality of service should be comparable with the service offered by standard digital connections. Class 2 specifies necessary service levels for packetized video and voice. Class 3 defines requirements for interoperability with other connection-oriented protocols, particularly frame relay. Class 4 specifies interoperability requirements for connectionless protocols, including IP, IPX, and SMDS. Class 5 is effectively a "best effort" attempt at delivery; it is intended for applications that do not require guarantees of service quality.

In conventional data networks, such as the typical Ethernet LAN or X.25 WAN, there are no explicit negotiations between the network and the user

specifying the traffic profile and quality of service expected. Rather, the network is expected to provide each user with a "fair share" of the available bandwidth.

However, in an ATM network, fair allocation of bandwidth requires users to adjust their transmission rates according to the feedback from the network. ATM networks carry fixed bandwidth services required for multimedia applications (constant bit rate (CBR) traffic) and guaranteed bandwidth services for high-priority data applications (variable bit rate (VBR) traffic). The remaining bandwidth, not used by guaranteed bandwidth services, must be shared fairly across all users. The ATM Forum refers to services that make use of this otherwise idle bandwidth as available bit rate (ABR) services.

Although these ABR applications must contend for remaining available bandwidth and would not provide specific throughput guarantees, the ABR applications still would require fair access to the available bandwidth with a minimum of cell loss. If ABR traffic had no mechanism to determine if sufficient bandwidth were available to handle the transmission on the network and traffic was simply fed in, network congestion might result in dropped cells, and application traffic might be lost. ABR flow control is an ATM layer service category for which the limiting ATM layer transfer characteristics provided by the network may change after establishing the network connection. A flow control mechanism is specified which supports several types of feedback to control the source rate in response to changing ATM layer transfer characteristics. When the network becomes congested, the end-stations outputting ABR traffic are instructed to reduce their output rate. It is expected that an end-system that adapts its traffic in accordance with the feedback will experience a low cell loss ratio and obtains a fair share of the available bandwidth according to a network-specific allocation policy. Cell delay variation is not controlled in this service, although admitted cells are not delayed unnecessarily.

In this end-to-end rate-based scheme, the source (e.g., a user remote site 103) of a virtual circuit (VC) indicates the desired rate in a resource management cell (RM cell). An RM cell is a standard 53-byte ATM cell used to transmit flow-control information. The RM cell travels on the VC about which it carries information, and is therefore allowed to flow all the way to the destination end-station (e.g., PC 119d). The destination reflects the RM cell, with an indicator to

show that the RM cell is now making progress in the reverse direction. The intermediate switches (e.g., switch 109) then identify within the reverse RM cell their respective maximum rates (the explicit rate allocated to the VC). After the source receives the reverse RM cell, the smallest rate identified in the reverse RM cell is then used for subsequent transmissions until a new reverse RM cell is received.

ATM has many recognized advantages and has dominated wide area networks (WANs) as the preferred backbone transport technology. Because of cost and performance factors, ATM faces stiff competition from both switched and shared-media high-speed LAN technologies, including Ethernet, Fast Ethernet, and Gigabit Ethernet. And although ATM typically offers QOS guarantees superior to the prioritization schemes of competing high-speed technologies, many users remain unable to take advantage of these features. If a remote user wishes to obtain the advantages of ATM, one solution would be to acquire an ATM switch on the premises as shown in Figure 1A. The remote site 103 would need to be equipped with an ATM switch 103a, whereby a PC 103b interfaces the ATM switch 103a via an ATM NIC 103c. In addition, the remote user would have to lease a T1 line or an OC-3c pipe from the Telco. The leased line would terminate in an ATM switch 109 in the CO 105. The CO ATM switch 109 is connected to the ATM network 113. With an ATM connection, the remote user may quickly access multimedia information on the Internet by establishing a virtual channel that would terminate at ATM switch 125 in CO 121. The CO 121 would of course have some means of communication with the ISP 117; typically routers (not shown) are used.

Alternatively, Figure 1B illustrates an ATM to the desktop solution whereby the xDSL technology is utilized to extend ATM capability remotely. At the customer premises 103, a PC 103b is equipped with an ATM NIC 103c, which is attached to an xDSL modem 103d. In addition, a telephone set 103e is linked to the xDSL modem 103d. The xDSL modem is connected over twisted pair copper wire to the CO 105, terminating at the POTS splitter 117. The POTS splitter 117 separates the data signals originating from the PC 103b from the voice signals. A xDSL multiplexer (mux) 115 receives the data signals from the POTS splitter and uplinks these signals to the ATM switch 105. Although the solution

present above provides a way to deliver ATM capabilities to the desktop, it disadvantageously requires the acquisition of ATM NICs by the remote users, and the xDSL modem has to have a costlier ATM interface.

Despite all the many inherent advantages with ATM, Ethernet-type LANs constitute nearly all of the networking resources of business and residential users. Moreover, these legacy systems are still being enhanced and marketed, e.g., switched Ethernet, switched Fast Ethernet, and switched Gigabit Ethernet are significantly lower cost than their ATM counterparts. ATM technology requires a substantial investment in infrastructure, from cable plant to switches to network interface cards (NICs). This tremendous investment cost can be sustained in the wide area network (WAN) where costs can be spread out. However, in the LAN environment, the investment in infrastructure is typically unsustainable which translates into retention of "legacy" LANs such as Ethernet.

While a number of service providers (e.g., Telcos) employ ATM to establish point-to-point circuits, little has been done to utilize ATM for transporting multimedia information or services to the desktop. This is simply not commercially practical. As previously noted, commercial practicality prohibits such an endeavor. In essence, millions of users would be required to purchase expensive ATM network interface cards, and then possibly add very costly T1, T3, or OC-3c lines. As a result, service providers have not commercially implemented ATM in the delivery of multimedia information to the desktop.

One apparent disadvantage with the current system of delivering multimedia information to the end-user or desktop is the slow speed associated with the wide area transmission mechanisms.

Another disadvantage is the inability to ensure an end-to-end quality of service regarding the transmission of the multimedia information.

Yet another disadvantage of conventional systems is a lack of real-time, rate-based, flow control which can provide congestion management.

Yet another disadvantage with the use of cell switching technology is the requirement that existing network interface devices, like Ethernet interfaces, be replaced with more costly and complex interfaces.

DISCLOSURE OF THE INVENTION

There is a need for an arrangement that enables the high-speed transmission of multimedia information to the desktop.

There is also a need for an arrangement that enables use of an Ethernet-type network interface device in the procurement of multimedia information from a cell switching network.

There is also a need for an arrangement that ensures an end-to-end quality of service in the delivery of multimedia information to the desktop and one which has real-time flow control capabilities needed to eliminate congestion in order to speed delay-sensitive traffic through the network.

There is also a need for providing the advantages of cell switching technology without having to replace legacy network interface cards.

These and other needs are attained by the present invention, where an Ethernet-type network interface device coupled to a remotely located host processor is connected to a high-speed subscriber interface. A multimedia switch is linked to the high-speed subscriber interface. The multimedia switch performs cell-to-Ethernet frame conversion, and vice versa. This communications network supports both native ATM applications, such as those based on the Winsock 2.0 Application Programming Interface (API) as well as traditional IP based applications. That is, when and if an application opens a socket to the ATM layer is the SHIM software invoked; otherwise, the conventional TCP/IP-NDIS driver is utilized. Where Winsock 2.0 enabled applications are utilized, ATM cells are encapsulated into variable length Ethernet frames; up to 31 ATM cells can be encapsulated into a single Ethernet frame. In so doing, ATM QOS and ABR/ER flow control are preserved, facilitating the timely transport of delay sensitive multimedia traffic.

According to one aspect of the present invention, a method in communication network, comprises processing data cells containing multimedia information and Ethernet type data frames containing the multimedia information; transporting the data frames to an Ethernet type network interface device via a high-speed subscriber interface; and ensuring a predetermined quality of service associated with the transport of the data frames as well as maintaining a congestion free environment through the use of explicit rate based flow control mechanisms featuring RM cell priority.

Another aspect of the present invention provides a communication network, comprising an Ethernet type network interface device configured for processing data frames containing multimedia information; a multimedia switch configured for providing quality of service and ABR/ER flow control capabilities and for translating the data frames into data cells and vice versa; and a high-speed subscriber interface configured for connecting the multimedia switch to the Ethernet type network interface device over a physical media.

Additional objects, advantages and novel features of the invention will be set forth in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference is made to the attached drawings, wherein elements having the same reference numeral designations represent like elements throughout and wherein:

Figures 1A and 1B are graphic representations of a prior art networks and the access methods;

Figure 2 is a graphic representation of a network embodying the system of the present invention;

Figures 3 is a graphic representation of another network embodying the invention;

Figure 4 is a block diagram depicting detailed aspects of the switch shown in the embodiments of Figures 2 and 3;

Figure 5 is a block diagram depicting a hardware embodiment of the switch of the present invention; and

Figure 6 is a block diagram depicting the protocol stack residing in the end-station.

BEST MODE FOR CARRYING OUT THE INVENTION

The present invention retains the traditional low cost and low complexity Ethernet NIC but achieves ATM capability over Ethernet through use of the software "shim" in the client computer and the multimedia switch in the central office.

Figure 2 illustrates an embodiment of the present invention taking advantage of the existing network media created by the telephone industry which implemented a vast network of copper twisted pair wiring to interconnect homes and businesses domestically and abroad. In Figure 2, a customer premises 200 is shown as comprising an end-station 210, such as a desktop computer residing in a home or business. Typically, such end-stations are either stand-alone desktop stations, or are already connected to a collocated local area network (LAN).

A variety of LAN technologies exist, but the large majority of LANs conform to the IEEE standard 802.3, which defines Ethernet standards. Various types of Ethernet systems exist such as switched Ethernet, Fast Ethernet, and Gigabit Ethernet.The end-station 210 is equipped with an Ethernet NIC 212 residing in a personal computer with a host processor 214. Ethernet NIC 214 is connected to a high-speed digital subscriber line (DSL) modem 220, which interfaces with a telephone line 222 via a CP (customer premise) POTS (plain old telephone service) splitter 221. The telephone line is a twisted pair copper wire, which the conventional customer premises telephone 224 uses to connect with a telephone central office 240. A telephone central office or end office is shown in Figure 2 as a communications facility 240; however, any communication facility can be used (e.g., a wire closet in a separate building).

High-speed communication to remote users depends largely on the method of access to the networking infrastructure. Most users cannot bear the cost of leasing expensive outside lines that are needed to provide high speed communication to the Internet or to their offices. The disclosed embodiment overcomes this dilemma by employing a high-speed, low cost subscriber interface that takes advantage of the legacy outside cable plant, such as standard twisted copper pair wiring and coaxial cables.

As illustrated in Figure 2, one embodiment utilizes digital subscriber line (DSL) technology to delivery the high bandwidth that the remote users demand. Because traditional copper cabling is used, the remote users do not have to

upgrade their current physical connection – their POTS line is sufficient. Because the outside plant need not be revamped, telephone companies (Telcos) can readily implement DSL services. The DSL modem 220 acts as the network access device to the central office. A DSL multiplexer 252 provides termination of the DSL modem connection within communications facility 240. DSL technology is categorized by the downstream and upstream bandwidths. The present invention could be applied to any of the various forms of DSL technology. One variety, commonly employed, Rate Adaptive DSL or RADSL, involves a rate negotiation between the customer premise DSL modem 220 and the Telco CO modem located within DSL MUX 252 which takes into account distance and line quality issues yielding the maximum available rate for the line conditions encountered. RADSL supports both Asymmetric DSL or ADSL, with a maximum downstream rate of 7.62 Mbps and a maximum upstream rate of 1.1 Mbps, which is ideal for very high speed Internet access and video-on-demand applications. ADSL services can be delivered up to 18,000 feet from the central office over a single copper twisted pair. RADSL also supports Symmetric DSL or SDSL, with a maximum bi-directional rate of about 1.1 Mbps, which is ideal for very high quality video-conferencing and remote LAN access. Another type of DSL technology is known as high-bit-rate digital subscriber line (HDSL), which provides a symmetric channel, delivering T1 rates (1.544 Mbps) in both directions. HDSL has a distance limitation of about 12,000 feet without repeaters. Telcos have traditionally used HDSL to provide local access to T1 services. HDSL is already widely deployed within the Telco market as a low cost T-1 replacement. VDSL or Very high bit-rate DSL requires a fiber-to-the curb local loop infrastructure, with asymmetric speeds up to 52 Mbps. Other flavors of DSL (i.e., sometimes generically denoted xDSL) are characterized by whether the service is asymmetric or symmetric and the bandwidth allocations for the upstream and downstream transmissions.

The central office 240 comprises a plain old telephone service (POTS) splitter 242 which receives the information transmitted across the twisted pair line 222 and "splits" the low frequencies, which carry voice signals, from the high frequencies, which carry data signals. Essentially, the POTS splitter is a passband filter, whereby the low frequency information is carried by a voice line 244 to a

voice switch 246 and ultimately to a public switched telephone network (PSTN) 248. The voice line 244, voice switch 246 and PSTN 248 are each conventional, and are therefore not explained further so as not to detract from the focus of the disclosure of the present invention.

The data information, which is modulated using high frequency signals, is transmitted over a twisted pair cable 250 to a POTS splitter 242. The POTS splitter 242 then passes the high frequency signals to a DSL multiplexer (DSL MUX) 252. The DSL MUX serves as the DSL modem termination point for numerous end users with DSL modems. The DSL MUX252 aggregates all the DSL traffic and passes the multimedia information to the multimedia switch 260. The traffic can be of any data type including multimedia graphics, video, image, audio, and text. Various embodiments of the DSL MUX 252 can be employed, ranging from 24 line stackable modules through the traditional high density chassis based approach. Various line codes can be supported within the DSL modems, including Carrierless Amplitude Phase (CAP) modulation, Discrete Multi-Tone (DMT) modulation, Quadrature Amplitude Modulation (QAM), as well as others. Multimedia switch 260 is primarily an edge device that is connected to an ATM network 270 on which a conventional multimedia server (not shown) may be linked. The ATM network 270 thus represents a fast and efficient delivery system for multimedia applications to which the end user desires access. The multimedia switch 260 communicates with the CO DSL MUX 252 relative to traffic information, in order to minimize congestion. Traditionally, end user access to an ATM network has been through a router. Since the end-station 210 houses an Ethernet NIC 214, connection to ATM network 270 proves difficult without the system of the present invention, which allows information residing on an ATM network to be transferred to an Ethernet end-station while still retaining all the multimedia benefits of ATM, including QOS and ABR/ER flow control. An advantage associated with a DSL implementation is that the personal computer is constantly connected, much like a typical Ethernet LAN connection. That is, communication sessions are not initiated through a dial-up procedure.

Figure 3 depicts a configuration similar to that of Figure 2, however, the system of Figure 3 takes advantage of the pre-existing coaxial cable network

established largely by the cable television industry to bring "cable TV" to homes and businesses. Due to the tremendous similarities between Figures 2 and 3, like numerals depict like elements.

The differences between Figures 2 and 3 center on using an existing coaxial cable 322 and using components similar to those disclosed in conjunction with Figure 2 which are adapted for the implementation shown in Figure 3. Customer premise 200' includes a cable modem 320 for the delivery of the requisite high bandwidth to the end user. Cable modem technology, in order to provide for bi-directional communications, requires a hybrid fiber/coax or HFC based system. This is requiring the cable TV industry to replace the existing cable infrastructure at great cost. HFC systems are only currently deployed in a very small minority of locations within the U.S.

Coaxial cable systems typically operate in the range of 330 MHz to 450 MHz; modern hybrid fiber/coax (HFC) systems can extend the frequency to greater than 750 MHz to provide significantly more TV channels. For data services, a cable modem headend system 346 creates a shared virtual LAN with the subscribers' cable modems, such as 320, as the network nodes. These cable modems conventionally are standalone units that connect to personal computer 210 through an Ethernet network interface (e.g., NIC 214) and standard twisted pair copper 347. The cable headend employs 64 quadrature amplitude modulation (QAM) to deliver a downstream bandwidth of up to 27 Mbps. This rate can be further increased by using 256 QAM. The upstream bandwidth typically ranges from 500 Kbps to 10 Mbps using 16 QAM or quadrature phase shift keying (QPSK). As in the DSL implementation, an advantage associated with the cable modem implementation is that the personal computer is constantly connected, much like a typical Ethernet LAN connection. That is, communication sessions are not initiated through a dial-up procedure.

A cable television distribution unit 342 provides an access point into the virtual LAN overlaid onto the cable system infrastructure 348. A cable interface multiplexer (cable MUX) 352 provides aggregation of cable channels from multiple CATV distribution units 326. The cable interface MUX 352 is also responsible for converting the QAM or QPSK signals into Ethernet signaling over twisted pairs, which connect into the multimedia switch 260. Figure 4 provides a

high level description of the multimedia switch, which comprises four basic components: a cell interface 401, a switching fabric 403, an Ethernet/Cell translator 405, and an Ethernet interface 407. The Ethernet interface 407 receives standard Ethernet frames (e.g., from a DSL MUX 252 or cable MUX 352). The Ethernet frame format conforms with all Ethernet type formats (e.g., IEEE 802.3/802.2, Ethernet II, Novell 802.3, and IEEE 802.3/802.2 SNAP). These Ethernet frames are then sent to the Ethernet/Cell translator 405, which converts Ethernet frames into cells as well as cells into Ethernet frames. The Ethernet frames to cells conversion involves segmenting the Ethernet frames and reassembling them as 53 bytes cells for transport over a cell switching backbone such as an ATM network. The conversion from cells into Ethernet frames is a simpler process, whereby the fixed length cells are encapsulated by the Ethernet frame, which can extend to 1500 bytes in length.

Once converted from Ethernet frames to cells, the cells are switched over the switching fabric to the cell interface for output into the cell-switching network. In one embodiment where Ethernet frames are routed to another Ethernet LAN, the Ethernet/Cell translator 405 does not perform frame to cell conversion, but instead, by-passes the switching fabric 403 and presents the Ethernet frame to the Ethernet interface 407 to be outputted. Alternatively, the Ethernet frames may be forced to undergo conversion into cells, thereby negating the requirement for a separate routing circuitry for the Ethernet frames; that is, the Ethernet frame is sent to its destination MAC address via the switching fabric 403.

The cell interface 401 comprises cell ports (not shown) for the inputting and outputting of data cells. In a typical ATM implementation, these ports are fiber optic connections, and the cell interface 401 handles OC-3c (155 Mbps) and OC-12 (622 Mbps) data rates. Lower data rates of DS1 (1.544 Mbps) and DS3 (44.7 Mbps) are also used; however, these rates typically employ copper cable connections.

The above discussion describes a generic multimedia switch. In accordance with the disclosed embodiment, the multimedia switch 260 can be a Cells-in-Frames (CIF) Ethernet switch with ATM functionality. CIF technology encapsulates ATM traffic within the frame structure of the existing LAN media

(such as Ethernet) in accordance with the Cells in Frames Version 1.0 Specification, incorporated herein by reference. CIF end stations (CIF ES) and CIF attachment devices (CIF AD), such as the multimedia switch 260, can thereby exchange native ATM traffic over the same LAN media that serves the standard frame-based traffic (e.g., IP and IPX).

From a simplistic perspective, CIF describes the method for utilizing frame-based LAN media as another ATM physical layer. The CIF protocol is a peer-to-peer protocol that maintains a virtual point-to-point link (the CIF link) between the CIF ES and the CIF AD that serves it. The CIF link is a virtual point-to-point connection between the CIF ES and the CIF AD that is carried over the LAN connecting them. The two sides of this virtual link maintain local connections of the status of the link. The CIF specification (version 1.0, incorporate herein by reference) describes the exact protocol for establishing the logical association between the CIF ES and the CIF AD and exchanging native ATM traffic encapsulated in specific Ethernet Version 2, IEEE 802.3, or IEEE 802.5 Token Ring frames.

The multimedia switch 260, in one embodiment, employs the CIF technology. The form factor of the multimedia switch 260, moreover is a stackable unit similar to the DLS MUX 252 such that the two units may reside within the same system rack. In addition, the stackable nature enables easy connectivity between the two units. A more detailed description of the multimedia switch 260 follows.

Figure 5 depicts a block diagram of a hardware configuration 500 illustrating an embodiment of switch 260 of the present invention. Hardware configuration 500 can be divided into the following major sections: an Ethernet interface 502; a DMA engine 504; an ATM interface 506; a packet buffer 508; a receive processor 510; a transmit processor 512; a communications processor 514; a boot and mail box section 516; a back-plane interface 518; and a power supply 520.

Ethernet interface 502 comprises 16 10/100 Mbps auto-negotiating Ethernet ports 502a. The Ethernet ports 502a handle information between Ethernet NIC 214 and DMA engine 504.

DMA engine 504 performs high-speed transfers of packets between the packet buffer 508 and all the network interfaces (Ethernet interface 502, ATM interface 506, and back-plane interface 518). DMA engine 504 also transfers packet pointer and other relevant information to receive processor 510. A RISC descriptor processor (DP) 504a assists DMA engine 504 by providing it with free receive buffers per port for receiving packets. DP 504a also frees transmitted buffers and links them to the free buffer chain.

In ATM interface 506, a RISC ATM Processor (AP) 506a runs the ATM driver code and handles frame reception from a pair ATM ports 506b and forwarding of the same to the packet buffer (through DMA engine 504) and vice versa. The ATM ports 506b are implemented as plug-in daughter cards. A local storage of 1MB/2MB memory is provided to act as buffer between two different busses (a PCI bus 522 on the SAR side, and a packet buffer bus 524) to which ATM interface 506 is connected. AP 506a also performs all the house-keeping related to the pair of ATM ports 506b.

Packet buffer 508 comprises 4 Mbytes of memory (expandable to 8MB) used for central storage of packets received from Ethernet interface 502, ATM interface 506 and Back-plane interface 518. A high-speed (64 bit, 66MHz) 4.2 Gbps bus 530 provides the interface to packet buffer 508.

Three processors handle all the packet processing. Receive processor (RP) 510 is a RISC processor that performs the switching functionality. It analyzes the packet headers and makes forwarding decisions. The processor also handles switching of CIF and non-CIF packets and routing of IP packets. Transmit Processor (XP) is a RISC processor that handles transmission of packets (i.e., traffic scheduling) and frame descriptor management. Communication Processor (CP) 514 runs, for example, the VxWorks real time operating system (RTOS) and handles all the remaining functions such as ATM signaling, Spanning tree protocol, TCP/IP, SNMP, house-keeping, etc. CP 514 has control over all the processors, and coordinates the booting of each of the processors on power up, and also monitors their functioning.

When a packet is received (from Ethernet interface 502, ATM interface 506 or back-plane interface 518), DMA engine 504 passes the pointer to the packet and other relevant information to RP 510, while storing the complete

packet in packet buffer 508. RP 510 reads the packet header from the packet buffer and does fast hash searches using the information in the header and makes appropriate forwarding decisions. The decisions are communicated to XP 512 through a mailbox within boot and mailbox section 516. XP 512 then handles queuing up of the packet in the appropriate transmit queue. In case RP 510 is not able to make the forwarding decision or if the packet requires special handling, then CP 514 is informed through another mailbox. The packet forwarding rate for RP 510 and XP 512 is approximately 1 million packets per second. The back-plane interface 518 is a 4.2 Gbps interface, and is treated by the controlling software as an Ethernet port having a lower priority than the ports of the Ethernet interface 502.

All the RISC processors (RP 510, XP 512, DP 504a and AP 506a) handle high-speed tasks. Traditionally, ASICs are employed for these tasks, but the present invention does not use ASICs and therefore provides greater flexibility in the implementation of programming changes and upgrades. The RISC processors run highly optimized code resident almost fully in on-chip caches. For example, Digital's StrongARM (SA110) processor is suitable for all the RISC processors (RP 510, XP 512, DP 504a and AP 506a). Digital's StrongARM (SA110) processor is high performance (233 MHz internal operation), yet consumes extremely low power (about half a watt). Intel's Pentium processor running at 133 MHz is suitable for CP 514.

Redundant, internal power supplies 520 provide suitable power for both the Telco and non-Telco environments using, respectively, a -48V input and universal AC input of 110-240V. In Figure 5, only one power supply 520 is shown for convenience. In the non-Telco environment, AC-DC supply modules are used, each having connectors feeding in 110-240VAC. In the Telco environment, the AC power supply is replaced by two DC-DC supply modules, each having connectors feeding in -48V DC.

The multimedia switch 260 as detailed above works in conjunction with the end-user-workstation's software to quickly deliver multimedia information while ensuring an end-to-end negotiated quality of service that is free from delay inducing congestion. Figure 6 illustrates in block diagram form the protocol stack implemented on end-station 210. This combination, or other suitable combination

of protocols, allows the implementation of CIF technology to bring native ATM services to desktops that are equipped with legacy Ethernet or Token Ring NICs by encapsulating cells into frames. CIF can also be viewed as the inverse of ATM LAN Emulation (LANE). LANE provides a way for legacy LAN media access controller-layer protocols like Ethernet and Token Ring, and all higher-layer protocols and applications, to access work transparently across an ATM network. LANE retains all Ethernet and Token Ring drivers and adapters; no modifications need to be made to Ethernet or Token Ring end stations. In other words, CIF emulates ATM services over frame-based LANs. CIF uses software at the workstation without requiring the procurement of a new NIC to support quality of service scheduling and ABR/ER flow control.

In a particularly useful embodiment, a shim 611 resides as a layer in end station 210 to provide encapsulation of cells within Ethernet frames in the desktop for transport to the data network. Shim 611 supports multiple queues, a scheduler (not shown), the ER flow control, and header adjustment. Shim 611 comprises an ATM Adaptation Layer (AAL) (not shown) which is the standards layer that allows multiple applications to have data converted to and from the ATM cell. AAL is protocol used that translates higher layer services into the size and format of an ATM cell. The CIF shim layer 611 also includes a traffic management (TM) component that sets forth the congestion control requirements. The TM component (not shown) can be implemented as TM 4.0. The ATM Forum has developed a complete 4.0 protocol suite that includes UNI signaling 4.0 (shown as ATM signaling 605) which allows signaling of bandwidth and delay requirements for QOS; whereby, TM 4.0 which specifies explicit rate flow control and QOS functions.

CIF shim layer 611 also includes a frame segmentation and reassembly (SAR) sublayer (not shown) which converts protocol data units (PDUs) into appropriate lengths and formats them to fit the payload of an ATM cell. At the destination end station, SAR extracts the payloads for the cells and converts them back into PDUs which can be used by applications higher up the protocol stack. The shim 611 adds the CIF header to packets before they are transmitted, and removes the header when they are received. The shim manages the message queues by queuing outgoing data into multiple queues for QOS management.

Shim 611 also processes the RM cells for explicit rate flow control using the ABR flow control and allows ATM signaling software to run both native ATM application as well as standard IP applications.

End station 210 further comprises a device driver 613 and a Network Device Interface Specification (NDIS) layer 609 located above the CIF shim layer 611. The end station 214 includes Internet Protocol (IP) layer 607b which supports classical IP, LANE and MPOA for the interworking of dissimilar computers across a network. IP layer 607b is a connectionless protocol that operates at the network layer (layer 3) of the OSI model. Winsock 2.0 603 is the application program interface (API) layer, which enables developers to take advantage of ATM's QOS and traffic management features. Application layer 601 can accommodate traditional as well as native ATM applications. Native ATM applications can be readily created with Winsock 2.0 API 603.

Null layer 606 provides a path for the CIF data packets after establishment of a connection. Furthermore, the arrangement depicted in Figure 6 guarantees that the services negotiated by the native ATM applications for the VCs are not arbitrarily disrupted by the traffic generated by the legacy applications. Forcing both the ATM and the legacy protocol traffic to go through CIF shim 611 allows CIF shim 611 to manage the transmission of all traffic according to the QOS specified for each traffic stream. To support the migration of legacy applications, the CIF AD forwards CIF traffic from the conventional LAN onto the ATM infrastructure for delivery to an ATM attached end station or to another CIF AD. The CIF ES is also required to run LANE, MPOA (Multiprotocol Over ATM), or Classical IP protocols. Network data from a legacy application is first handled by the legacy protocols (e.g., TCP/IP), and then turned into ATM traffic by LANE, MPOA, or Classical IP. The CIF ES function encapsulates the individual cells into CIF frames before data is finally transmitted on the wire to the CIF AD.

In conclusion, the embodiments described above disclose a communication network that includes an Ethernet-type network interface device coupled to a host processor; a shim software, executed by the host processor, which supports ATM quality of service and ATM traffic management capabilities; a high-speed subscriber modem coupled to the Ethernet-type network interface device; a multiplexer connected to the high-speed subscriber modem

over a communication line; and a multimedia switch coupled to the multiplexer, wherein the multimedia switch encapsulates a plurality of data cells into one or more data frames, and supports available bit rate (ABR) with explicit rate flow control capabilities.

Also disclosed is communications network comprising an Ethernet type network interface device configured for processing data frames containing multimedia information, the Ethernet type network interface device coupled to a host processor, wherein the host processor is configured for supporting ATM quality of service and ATM traffic management capabilities; a multimedia switch configured for providing ATM quality of service and ATM traffic management capabilities and for translating the data frames into data cells and vice versa; a multiplexer coupled to the multimedia switch and configured for transferring the data frames to and from the multimedia switch; and a high-speed subscriber modem configured for connecting the multimedia switch to the Ethernet type network interface device to the multiplexer over a physical media.

Furthermore, a method in communication networks is disclosed which performs the steps of processing data cells containing multimedia information encapsulated by Ethernet type data frames; transporting the data frames to and from an Ethernet type network interface device via a high-speed subscriber modem connected to a multiplexer; and providing ATM quality of service and ATM traffic management capabilities associated with the transporting step.

These networks and methods for use on the networks: enable high-speed transmission of multimedia information to the network interface device coupled to a host processor; enable use of an Ethernet-type network interface device in the procurement of multimedia information from a cell switching network; ensure an end-to-end quality of service along with real-time rate-based flow control in the delivery of multimedia information to the network interface device coupled to a host processor; and provide the advantages of cell switching technology without having to replace the legacy network interface device.

While this invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but,

on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A communication network comprising:

an Ethernet-type network interface device coupled to a host processor;

a shim software, executed by the host processor, which supports ATM quality of service and ATM traffic management capabilities;

a high-speed subscriber modem coupled to the Ethernet-type network interface device;

a multiplexer connected to the high-speed subscriber modem over a communication line; and

a multimedia switch coupled to the multiplexer, wherein the multimedia switch encapsulates a plurality of data cells into one or more data frames, and supports available bit rate (ABR) with explicit rate flow control capabilities.

2. The communication network as in claim 1, wherein the high-speed subscriber modem comprises a digital subscriber line (DSL) modem, and the multiplexer comprises a DSL multiplexer.

3. The communication network as in claim 2, wherein the multimedia switch is located at a telephone communications facility, and the DSL is connected to the multiplexer via copper twisted pair lines.

4. The communication network as in claim 1, wherein the high-speed subscriber modem comprises a cable modem, and the multiplexer comprises a cable interface multiplexer.

5. The communication network as in claim 4, wherein the multimedia switch is located at a cable television distribution unit, and the cable modem is connected to the cable interface multiplexer via coaxial lines.

6. The communication network as in claim 1, wherein the data cells are ATM cells and the data frames are Ethernet-type data frames.

7. The communication network as in claim 1, wherein the available bit rate (ABR) with explicit rate flow control supports resource management (RM) cell priority.

8. The communication network as in claim 1, wherein the multimedia switch further comprises:

a first port;

an Ethernet frame/cell translator coupled to the first port;

a switching fabric for receiving the output of the Ethernet frame/cell translator; and

a second port coupled to the switching fabric for interfacing with external networking systems,

wherein the first port is connected to a port on the multiplexer.

9. The communication network as in claim 1, wherein the host processor is remotely located from the multimedia switch.

10. A communication network, comprising:

an Ethernet type network interface device configured for processing data frames containing multimedia information, the Ethernet type network interface

device coupled to a host processor, wherein the host processor is configured for supporting ATM quality of service and ATM traffic management capabilities;

a multimedia switch configured for providing ATM quality of service and ATM traffic management capabilities and for translating the data frames into data cells and vice versa;

a multiplexer coupled to the multimedia switch and configured for transferring the data frames to and from the multimedia switch; and

a high-speed subscriber modem configured for connecting the multimedia switch to the Ethernet type network interface device to the multiplexer over a physical media.

11. The communication network as in claim 10, wherein the high-speed subscriber modem comprises a DSL modem, and the multiplexer comprises a DSL multiplexer.

12. The communication network as in claim 11, wherein the physical media comprises twisted pair copper wire.

13. The communication network as in claim 10, wherein the high-speed subscriber modem comprises a cable modem.

14. The communication network as in claim 13, wherein the physical media comprises coaxial cable.

15. The communication network as in claim 13, wherein the physical media comprises coaxial cable and fiber optic cable.

16. The communication network as in claim 10, wherein the ATM traffic management capability provides available bit rate (ABR) explicit rate flow control.

17. The communication network as in claim 16, wherein the available bit rate (ABR) with explicit rate flow control includes resource management (RM) cell priority.

18. A method in communication networks, comprising:

processing data cells containing multimedia information encapsulated by Ethernet type data frames;

transporting the data frames to and from an Ethernet type network interface device via a high-speed subscriber modem connected to a multiplexer; and

providing ATM quality of service and ATM traffic management capabilities associated with the transporting step.

19. The method in claim 18, wherein the high-speed subscriber modem is either a DSL modem or a cable modem, the multiplexer providing a corresponding port for connection.

20. The method in claim 18, wherein the ATM traffic management capability provides available bit rate (ABR) with explicit rate flow control.

21. The method in claim 18, wherein the available bit rate (ABR) with explicit rate flow control supports resource management (RM) cell priority.

22. The method in claim 18, wherein the processing step utilizes cells-in-frames technology.

23. The method in claim 18, wherein the providing step supports the ATM quality of service and ATM traffic management capabilities end to end via a shim software.

FIG. 1A Prior Art

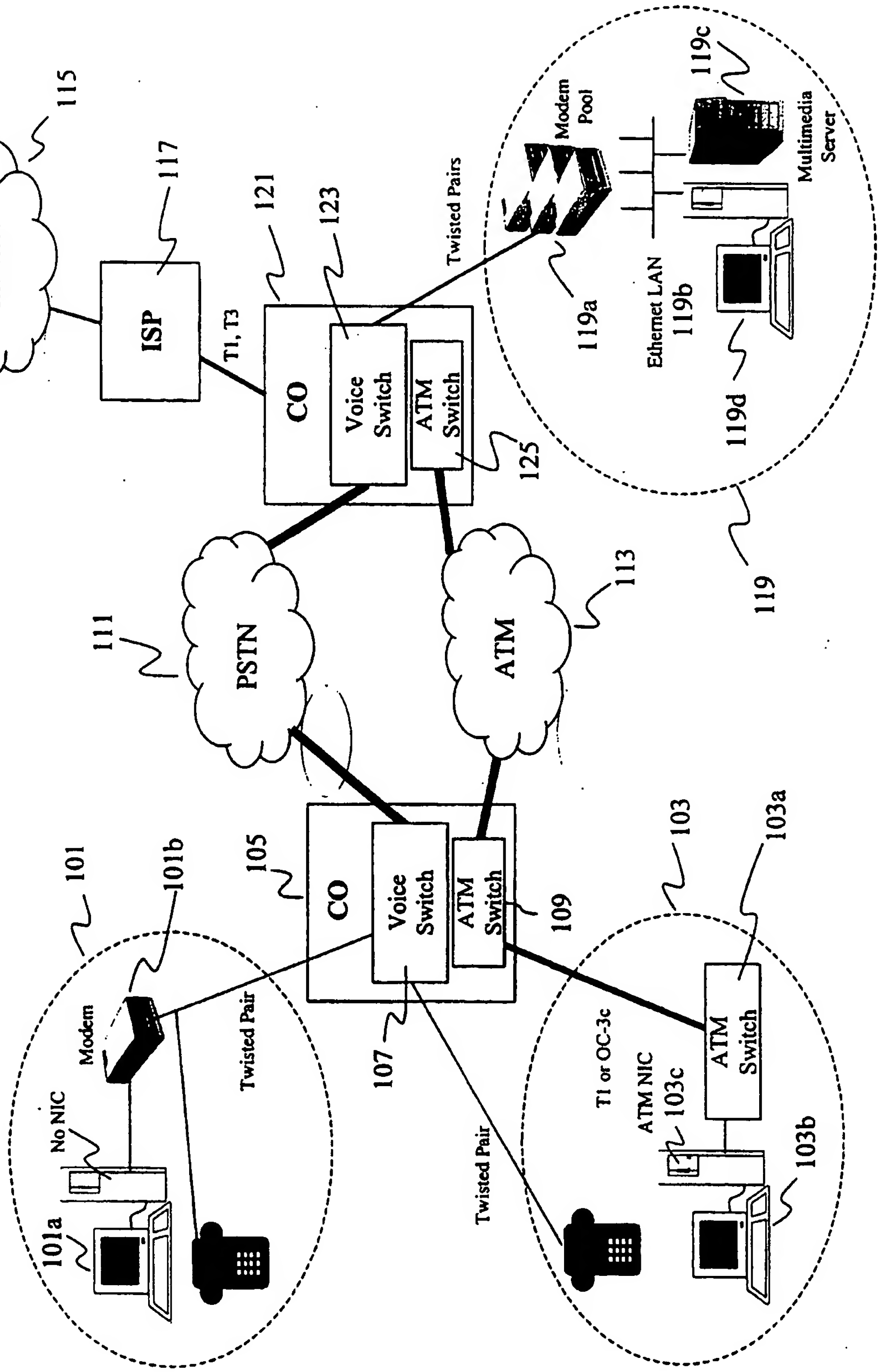


FIG. 1B Prior Art

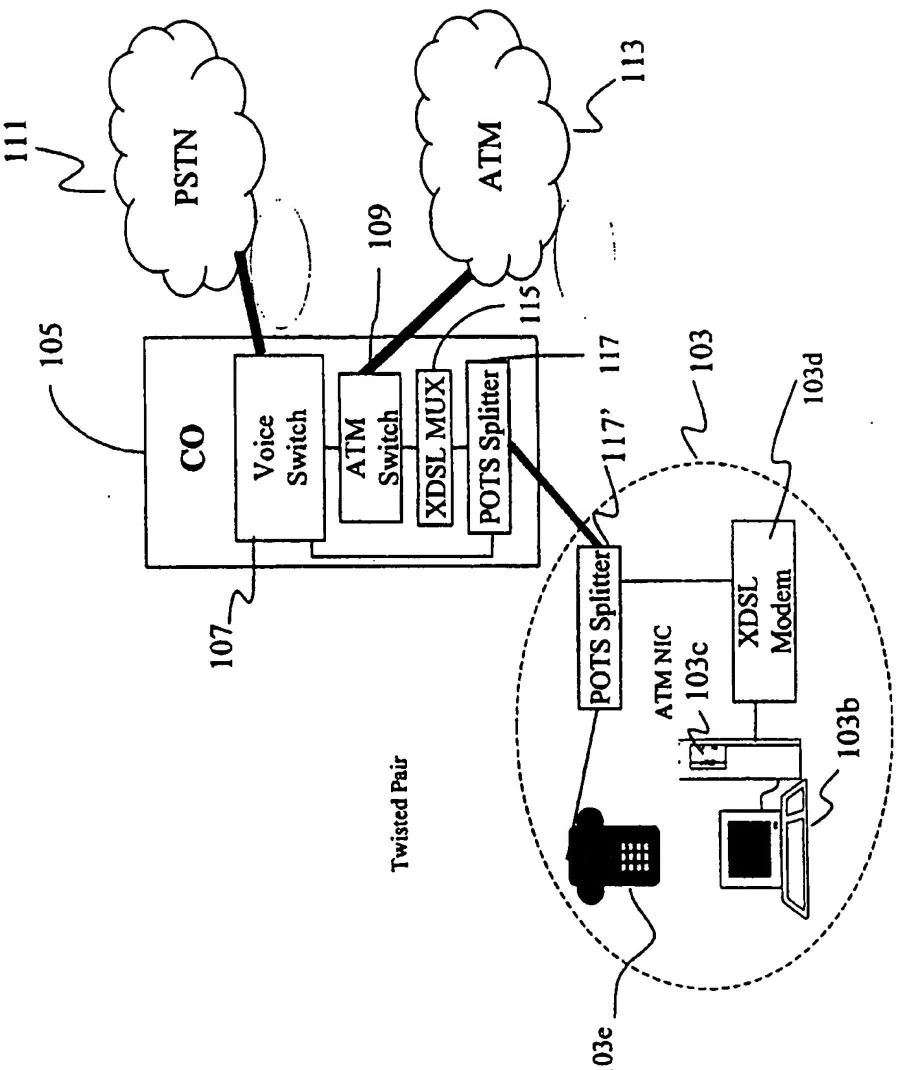
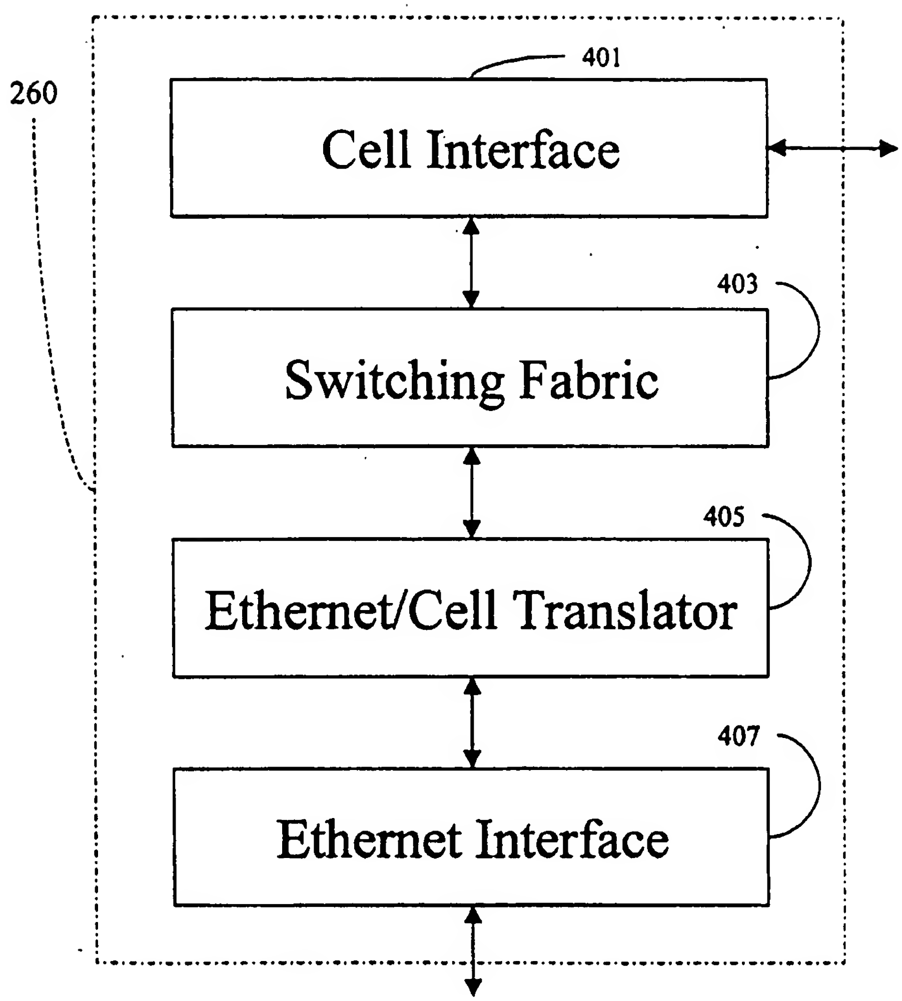


Fig. 2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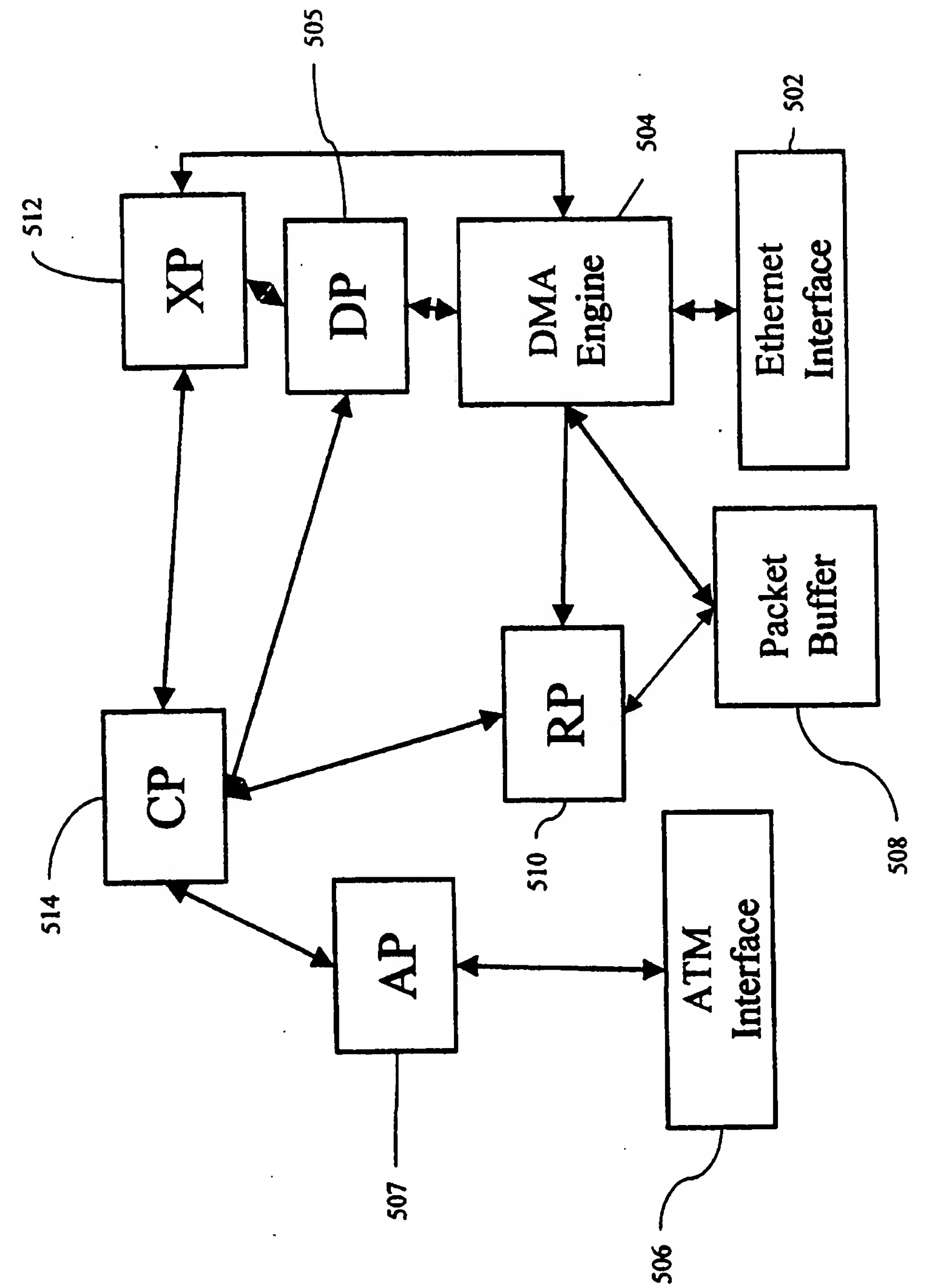
403
Switching Fabric
405
Ethernet/Cell Translator
407
Ethernet Interface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DP
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DMA
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RP
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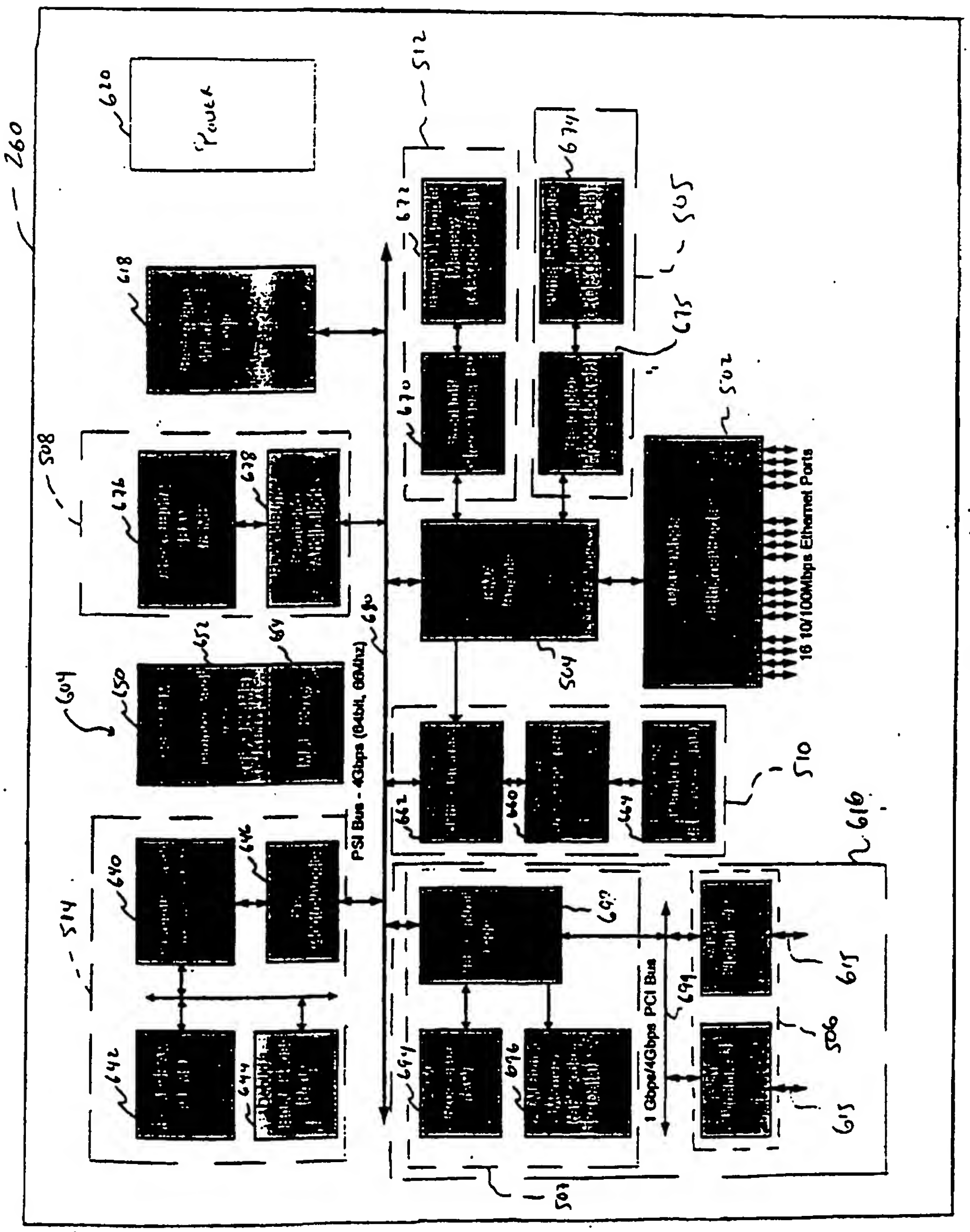
ATM
Interface
506

Fig.3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620
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618
508
676
678
604
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654
680
PSI Bus - 4Gbps (64bit, 66Mhz)
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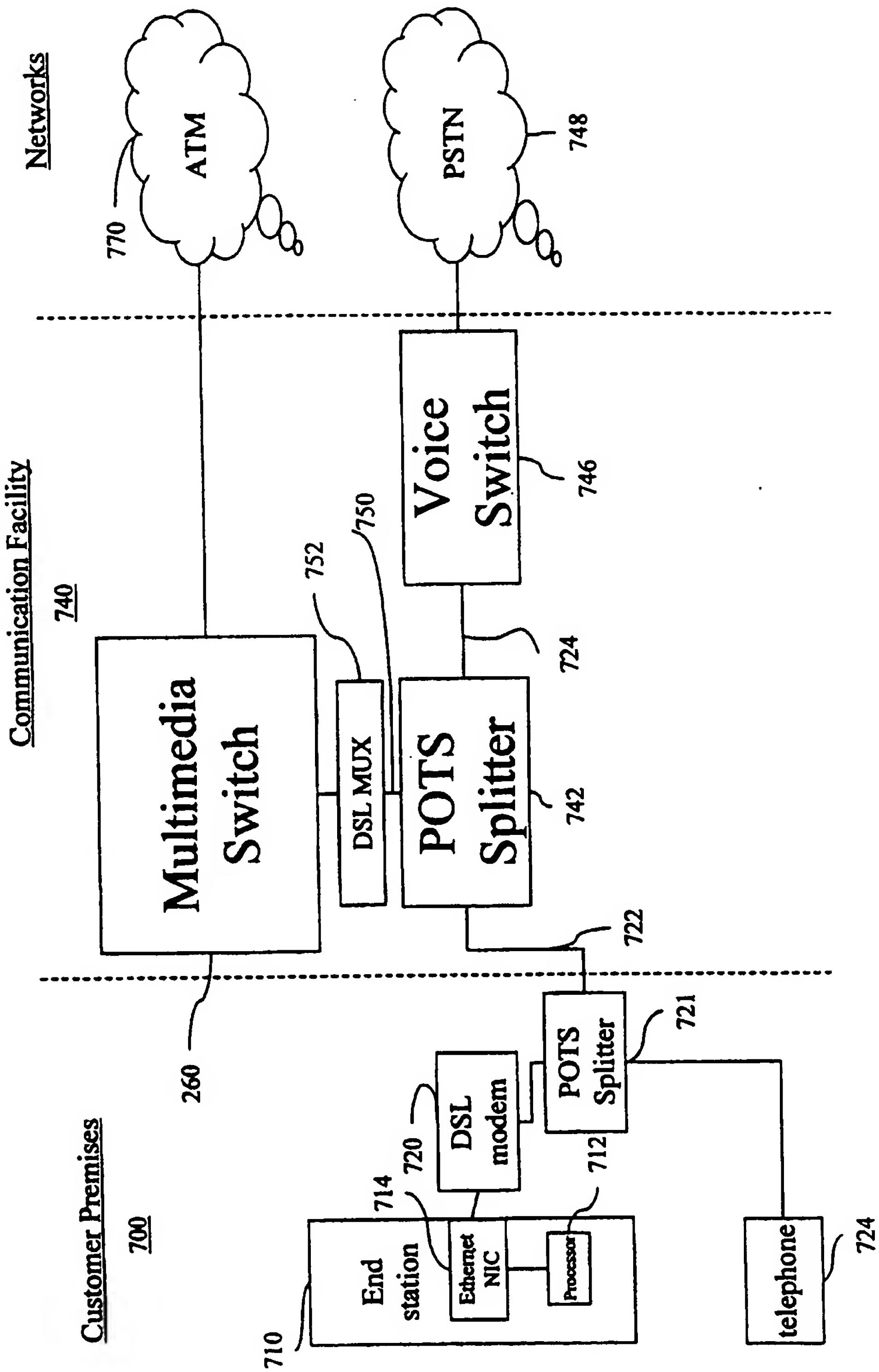
646
642
644
512
672
670
505
674
675
502
504
16 10/100Mbps Ethernet Ports
510
662
660
664
616
692
1 Gbps/4Gbps PCI Bus
694
691
696
615
506
503

FIG. 4



Networks
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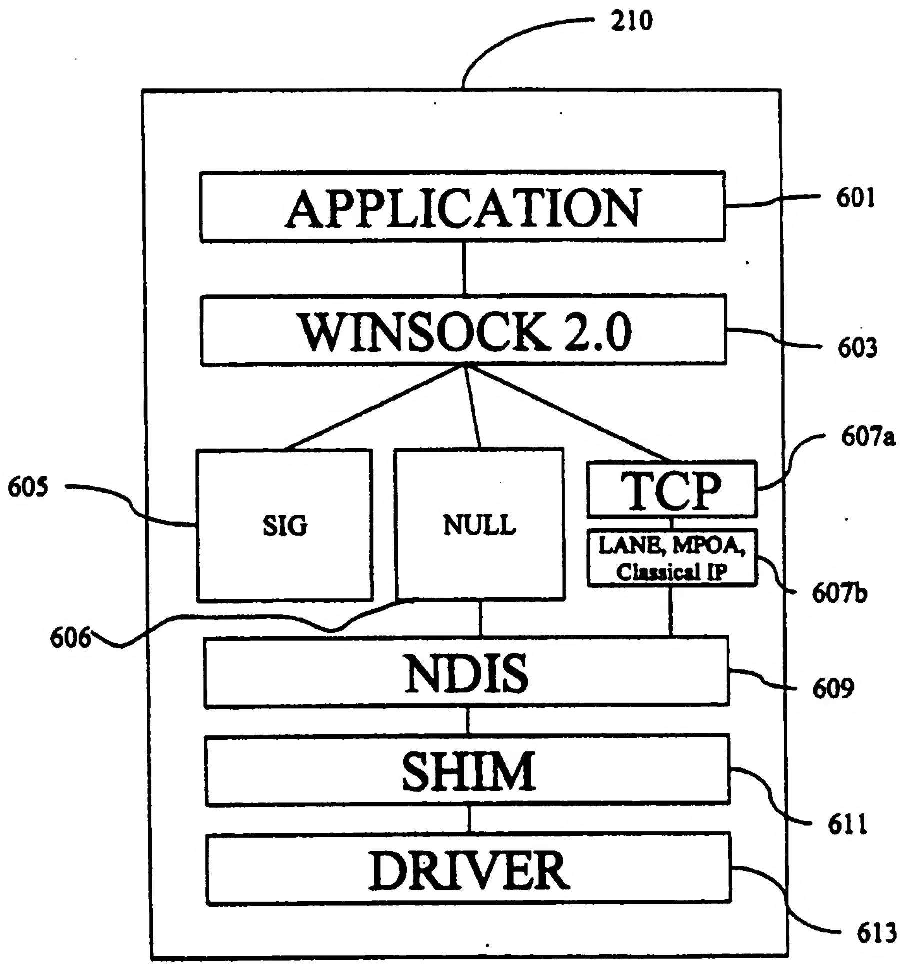
ATM
PSTN
748
Communication Facility
740
Multimedia Switch
DSL MUX
752
750
Voice Switch
746
POTS Splitter
742
724
722
260
Customer Premises
700
POTS Splitter
721
DSL modem
720
712
714
End station
Ethernet NIC
Processor
710
telephone
724

Fig. 5

Fig. 6


210
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603
607a
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TCP
LANE, MPOA, Classical IP
607b
606
NDIS
609
SHIM
611
DRIVER
613

INTERNATIONAL SEARCH REPORT

Inte. ,onal Application No
PCT/US 00/29357

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q11/04 H04L12/64

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	COHEN R: "SERVICE PROVISIONING IN AN ATM-OVER-ADSL ACCESS NETWORK" IEEE COMMUNICATIONS MAGAZINE,US,IEEE SERVICE CENTER. PISCATAWAY, N.J, vol. 37, no. 10, October 1999 (1999-10), pages 82-87, XP000859203 ISSN: 0163-6804 page 82, column 2, line 10 - line 35 page 83, column 1, line 1 - line 19 figures 1,3,6 page 84, column 2, line 29 - line 39 --- -/--	1,2,6,7, 10-23

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 March 2001	02/04/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lamadie, S

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/29357

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SHORE M ET AL: "Cells in frames: ATM over legacy networks" 1998 1ST IEEE INTERNATIONAL CONFERENCE ON ATM. ICATM'98, PROCEEDINGS OF ICATM'98: IEEE INTERNATIONAL CONFERENCE ON ATM, COLMAR, FRANCE, 22-24 JUNE 1998, pages 418-422, XP002163126 1998, New York, NY, USA, IEEE, USA ISBN: 0-7803-4982-2 figures 1,2,8 page 418, column 2, line 4 -page 419, column 1, line 20 page 420, column 1, line 5 - line 17 page 420, column 2, line 9 - line 15	1,2,6,7, 10-23
X	PAPA DEL J ET AL: "DSLAM - A BROADBAND DIGITAL SUBSCRIBER LINE ACCESS MULTIPLEXER SYSTEM" NEC RESEARCH AND DEVELOPMENT,NIPPON ELECTRIC LTD. TOKYO,JP, vol. 40, no. 1, January 1999 (1999-01), pages 103-107, XP000883831 ISSN: 0547-051X	18,19
A	figures 1,2 abstract page 103, column 2, paragraph 3 -page 104, column 1, line 5 page 104, column 2, paragraph 4 page 105, column 1, line 29 - line 31	1,10,20
A	ARCO J M ET AL: "Carrying ATM cells over Ethernet" PROCEEDINGS 25TH EUROMICRO CONFERENCE. INFORMATICS: THEORY AND PRACTICE FOR THE NEW MILLENNIUM, PROCEEDINGS OF EUROMICRO WORKSHOP, MILAN, ITALY, 8-10 SEPT. 1999, pages 342-349 vol.2, XP002163127 1999, Los Alamitos, CA, USA, IEEE Comput. Soc, USA ISBN: 0-7695-0321-7 figures 1,2 abstract page 342, column 2, line 1 - line 13	1,10,18

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